同行专家业内评价意见书编号：20250855135

附件1

浙江工程师学院（浙江大学工程师学院）
同行专家业内评价意见书

姓名：何平

学号：22260207

申报工程师职称专业类别（领域）：机械

浙江工程师学院（浙江大学工程师学院）制

2025年05月22日

填表说明

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四、同行专家业内评价意见书编号由工程师学院填写，编号规则为：年份4位＋申报工程师职称专业类别(领域)4位+流水号3位，共11位。

一、个人申报

（一）基本情况【围绕《浙江工程师学院（浙江大学工程师学院）工程类专业学位研究生工程师职称评审参考指标》，结合该专业类别(领域)工程师职称评审相关标准，举例说明】

1.对本专业基础理论知识和专业技术知识掌握情况(不少于200字)

作为一名硕士三年级的学生，我对机器人与机械专业的基础理论知识和专业技术知识有了较为系统和深入的掌握。在基础理论方面，我系统学习了工程力学、机械原理、机械设计、自动控制原理、机器人学等核心课程。通过这些课程的学习，我能够熟练运用牛顿力学、拉格朗日力学等理论分析机械系统的运动与受力情况，掌握了机械结构的设计与分析方法，能够对常见的机械传动、机构运动进行建模与仿真。

在机器人学方面，我深入学习了机器人运动学、动力学、轨迹规划、传感与感知、控制算法等内容。能够独立推导和分析串联、并联机器人机构的正逆运动学、雅可比矩阵及其在速度与力分析中的应用。对于动力学建模，我能够利用拉格朗日法和牛顿-欧拉法建立机器人动力学方程，并结合实际需求进行简化和求解。在轨迹规划方面，熟悉常用的插值算法和路径优化方法，能够根据任务需求设计合理的运动轨迹。

在自动控制领域，我掌握了经典控制理论与现代控制理论，包括PID控制、状态空间法、鲁棒控制、自适应控制等。能够针对不同类型的机器人系统设计合适的控制器，并通过MATLAB/Simulink等仿真工具进行验证和优化。此外，我还学习了传感器与执行器的原理及其在机器人系统中的集成应用，能够根据实际需求选择和集成合适的传感与驱动方案。

在专业技术方面，我具备较强的工程实践能力。熟悉常用的机械设计软件（如SolidWorks、AutoCAD）、机器人仿真与编程平台（如ROS、V-REP、Gazebo），能够进行机械结构建模、运动仿真与路径规划。具备一定的嵌入式系统开发能力，能够基于Arduino、STM32等平台进行机器人硬件开发与调试。参与过多项机器人相关的科研项目和竞赛，积累了丰富的团队协作和项目管理经验。

总之，经过三年的系统学习和实践锻炼，我不仅掌握了机器人与机械专业的基础理论知识，还具备了较强的专业技术能力和工程实践能力，为今后的科研工作和工程应用打下了坚实的基础。

2.工程实践的经历(不少于200字)

在硕士阶段的学习和科研过程中，我积极参与了多个与移动机器人相关的工程实践项目，积累了丰富的动手经验和系统集成能力。以下结合上述研究内容，详细阐述我的工程实践经历，重点突出在机器人平台设计、视觉SLAM系统构建及目标检测算法应用等方面的具体工作。

首先，在移动机器人平台的设计与制作方面，我主导并参与了基于两轮差分结构的移动机器人底盘的开发。通过查阅大量文献和资料，我深入分析了底盘的动力学和运动学模型，利用SolidWorks完成了机械结构的三维建模，并结合有限元分析对关键部件进行了强度和刚度校核。在实际制作过程中，我负责选型电机、驱动器及传感器，搭建了完整的硬件系统。针对轮式机器人常见的打滑问题，我尝试了多种悬挂结构设计，并通过实验对比，最终选定了最优方案，有效提升了机器人在不同地形下的稳定性和通过性。

在机器人自主定位与导航方面，我参与了基于视觉SLAM系统的开发。针对纯视觉定位在弱纹理环境下不稳定的问题，我深入研究了特征点提取与跟踪算法，并结合里程计信息，采用融合优化的方法提升了系统的鲁棒性和精度。具体实践中，我利用开源的ORB-SLAM2框架，结合自制机器人平台进行多场景测试，针对实际运行中出现的漂移和丢失问题，反复调试参数并优化算法流程，显著提升了系统在复杂环境下的定位稳定性。

在目标检测与抓取实验方面，我基于YOLOv5算法框架，改进了损失函数和激活函数，并引入注意力机制，提升了目标检测的准确率。为满足机器人自主抓取的需求，我还参与制作了金

属样品数据集，并设计了机械臂末端执行器，实现了对常见物品的识别与抓取。整个过程中，我不仅负责算法的训练与测试，还参与了机械臂的运动规划与控制，实现了从目标检测到自主抓取的完整闭环。

通过上述工程实践，我不仅提升了机器人系统的集成与调试能力，还锻炼了跨学科协作和解决实际问题的能力。这些经历为我后续从事机器人相关的科研和工程应用奠定了坚实的基础。

3. 在实际工作中综合运用所学知识解决复杂工程问题的案例（不少于1000字）

在我参与的一个工业级移动机器人研发项目中，我们面临着一个复杂的工程挑战：设计并实现一套能在复杂环境中自主定位、导航并精确抓取特定目标物体的机器人系统。该项目旨在解决传统工业环境中人工搬运效率低、劳动强度大的问题，同时探索机器人在非结构化环境中的应用潜力。

1. 系统整体架构设计

首先，我们搭建了基于麦克纳姆轮的全向移动机器人平台作为系统载体。麦克纳姆轮结构使机器人能够实现全向运动，大大提高了系统在狭小空间的机动性。我们分析设计了软件系统结构，并针对麦克纳姆轮全向底盘建立了正逆运动学模型。基于标准DH建模法对机械臂进行建模，得出其正逆运动学模型，为后续的路径规划和控制奠定了理论基础。通过实验测试，机械臂的运动控制精度平均相对误差为2.30%，满足了工程应用需求。

2. 目标检测算法优化

针对工业环境中目标物体识别的挑战，我们基于YOLO系列目标检测算法进行了深度优化。首先分析了YOLO系列算法的检测原理，然后引入了YOLOv8网络，并从Backbone、Neck和Head三个层面详细分析了其结构。为了提高检测精度并保证轻量化，我们利用Ghost模块和DFC注意力机制，用GhostBottleneckV2模块替换了YOLOv8中的CSP_2C_f模块，同时结合深度可分离卷积构建了GD-YOLO模型。

在损失函数方面，我们详细研究了用于分类的VariFocal Loss以及用于边界框回归的Complete-IoU Loss和Distribution Focal Loss，并设计了任务对齐的动态正负样本匹配策略和特殊的数据增强策略。经过在MessyTable数据集上的实验验证，优化后的GD-YOLO模型参数量仅为1.87M，在NVIDIA GeForce RTX 4090上的推理速率和帧率分别为13.27ms和43.82FPS，每秒执行浮点运算次数GFLOPs为7.7，同时mAP@50指标达到了0.670，大幅优于原始YOLOv8n模型，更适合部署于移动机器人的边缘计算设备。

3. 单目深度估计技术创新

为解决传统视觉定位系统在弱纹理环境下运行不稳定的问题，我们开发了一种轻量化的单目深度估计网络。我们分析了利用神经网络实现单目深度估计的算法原理，引入了边缘信息作为深度估计的结构化先验知识。

我们提出了基于交叉注意力机制的边缘特征融合模块CAFM，并基于该模块构建了双编码器结构的单目深度估计网络CAEFDepth。该网络包含两种编码器：提取语义信息的TokenPyramid和提取边缘信息的EdgeNet，以及基于CAFM构建的特征融合部分和解码器结构。经过在NYU Depth V2数据集上的实验，CAEFDepth网络模型总参数量仅为3.29M，在输入分辨率为480×640的情况下，在NVIDIA GeForce RTX 4090和NVIDIA Jetson Nano上的推理帧率FPS分别为67.36和6.10，衡量准确性的指标中RMSE、Rel和Log10分别为0.475、0.130和0.055，δ_1为0.841，推理速率接近SOTA模型而准确性指标基本超越SOTA模型。

4. 视觉定位系统集成与应用

针对传统视觉定位算法中的尺度不明问题，我们设计了DEB-VO算法系统，该系统包含特征检测与匹配、深度估计、尺度估计和位姿求解四大模块。我们基于FAST关键点和BRIEF描述子改进了ORB特征点，引入了旋转不变性和图像金字塔改善尺度问题。在匹配算法方面，我们采用基于FLANN的快速近似最近邻匹配算法，选择LSH作为数据结构，使用KNN进行匹配。

在尺度估计模块中，我们改进了传统的三角测量算法，提出了基于RANSAC的同时结合三角测量与深度估计模型的尺度恢复方法。从2D-2D以及3D-2D两种匹配维度出发，我们详细分析了对极几何约束下的本质矩阵E、基础矩阵F和特征点共面约束下的单应矩阵H及其求解方法。

5. 系统集成与实验验证

完成各模块开发后，我们进行了系统集成与实验验证。首先在实验室环境中制作了目标数据集，并利用我们开发的GD-YOLO模型进行微调迁移学习。结合坐标系变换和深度相机，我们实现了目标的3D坐标获取。在静态点位抓取实验中，系统总体平均抓取率达到80.83%，总体平均抓取耗时为8.37s。进一步构建室内实验场景，我们对比分析了DEB-VO与其他定位算法的效果，并选用Gmapping作为建图算法，比较了基于WO和DEB-VO在不同场景下的建图效果。

最终，我们基于ROS的Navigation框架实现了机器人的自主导航功能，并开展了完整的导航加抓取特定目标物体的实验。在动态场景中，系统平均抓取率为68.33%，机器人从出发点到目的地完成抓取的平均时间为57.1s。

这个项目不仅解决了实际工程问题，也验证了我们在目标检测、深度估计和视觉定位等方面的技术创新，为移动机器人在工业环境中的应用提供了有价值的参考方案。

（二）取得的业绩（代表作）【限填3项，须提交证明原件（包括发表的论文、出版的著作、专利证书、获奖证书、科技项目立项文件或合同、企业证明等）供核实，并提供复印件一份】

1.
公开成果代表作【论文发表、专利成果、软件著作权、标准规范与行业工法制定、著作编写、科技成果获奖、学位论文等】

成果名称	成果类别 [含论文、授权专利（含发明专利申请）、软件著作权、标准、工法、著作、获奖、学位论文等]	发表时间/授权或申请时间等	刊物名称/专利授权或申请号等	本人排名/总人数	备注
一种两轮差速移动机器人底盘	发明专利申请	2023年08月29日	申请号：202311098203.4		
Modeling and Control of Differential-Drive Chassis for a Homecare Assistive Robot	会议论文	2023年04月27日	论文链接：https://xplorestaging.ieee.org/document/10228142		

2. 其他代表作【主持或参与的课题研究项目、科技成果应用转化推广、企业技术难题解决方案、自主研发设计的产品或样机、技术报告、设计图纸、软课题研究报告、可行性研究报告、规划设计方案、施工或调试报告、工程实验、技术培训教材、推动行业发展中发挥的作用及取得的经济社会效益等】

（三）在校期间课程、专业实践训练及学位论文相关情况	
课程成绩情况	按课程学分核算的平均成绩： 86 分
专业实践训练时间及考核情况(具有三年及以上工作经历的不作要求)	累计时间： 1 年（要求1年及以上） 考核成绩： 81 分
本人承诺	
个人声明：本人上述所填资料均为真实有效，如有虚假，愿承担一切责任，特此声明！ **申报人签名：** 何平	

22260207

二、日常表现考核评价及申报材料审核公示结果

日常表现 考核评价	非定向生由德育导师考核评价、定向生由所在工作单位考核评价： ☑优秀　　☐良好　　☐合格　　☐不合格 德育导师/定向生所在工作单位分管领导签字（公章）：　　2025年5月26日
申报材料 审核公示	根据评审条件，工程师学院已对申报人员进行材料审核（学位课程成绩、专业实践训练时间及考核、学位论文、代表作等情况），并将符合要求的申报材料在学院网站公示不少于5个工作日，具体公示结果如下： ☐通过　　☐不通过（具体原因：　　　　　　　　　　） 工程师学院教学管理办公室审核签字（公章）：　　年　月　日

浙 江 大 学 研 究 生 院

攻读硕士学位研究生成绩表

学号：22260207	姓名：何平	性别：男	学院：工程师学院	专业：机械	学制：2.5年
毕业时最低应获：24.0学分		已获得：28.0学分		入学年月：2022-09	毕业年月：
学位证书号：			毕业证书号：		授予学位：

学习时间	课程名称	备注	学分	成绩	课程性质	学习时间	课程名称	备注	学分	成绩	课程性质
2022-2023学年秋季学期	工程技术创新前沿		1.5	82	专业学位课	2022-2023学年夏季学期	研究生英语基础技能		1.0	免修	公共学位课
2022-2023学年秋季学期	金属学原理与先进合金材料		2.0	82	专业学位课	2022-2023学年夏季学期	研究生论文写作指导		1.0	92	专业学位课
2022-2023学年秋季学期	人工智能算法与系统		2.0	94	专业选修课	2022-2023学年春夏学期	优化算法		3.0	92	专业选修课
2022-2023学年秋冬学期	工程伦理		2.0	84	公共学位课	2022-2023学年春夏学期	高阶工程认知实践		3.0	86	专业学位课
2022-2023学年冬季学期	材料现代研究方法与应用实践		2.0	92	专业学位课	2022-2023学年夏季学期	研究生英语		2.0	免修	公共学位课
2022-2023学年冬季学期	新时代中国特色社会主义理论与实践		2.0	92	公共学位课	2023-2024学年秋季学期	创新创业实践训练		2.0	通过	跨专业课
2022-2023学年冬季学期	产业技术发展前沿		1.5	91	专业学位课		硕士生读书报告		2.0	通过	
2022-2023学年春季学期	自然辩证法概论		1.0	79	公共学位课						

说明：1. 研究生课程按三种方法计分：百分制，两级制（通过、不通过），五级制（优、良、中、及格、不及格）。

2. 备注中“*”表示重修课程。

学院成绩校核章：

成绩校核人：张梦依

打印日期：2025-06-03

国 家 知 识 产 权 局

310013
浙江省杭州市西湖区古墩路 701 号紫金广场 C 座 1506 室 杭州求是专利事务所有限公司
林超(0571-87911726-817)

发文日：

2023 年 08 月 29 日

申请号：202311098203.4　　发文序号：2023082902545660

专 利 申 请 受 理 通 知 书

根据专利法第 28 条及其实施细则第 38 条、第 39 条的规定，申请人提出的专利申请已由国家知识产权局受理。现将确定的申请号、申请日等信息通知如下：

申请号：2023110982034
申请日：2023 年 08 月 29 日
申请人：浙江大学
发明人：杨赓,何平,吕鸿昊,杨华勇
发明创造名称：一种两轮差速移动机器人底盘
经核实，国家知识产权局确认收到文件如下：
权利要求书 1 份 2 页,权利要求项数 ： 7 项
说明书 1 份 7 页
说明书附图 1 份 5 页
说明书摘要 1 份 1 页
专利代理委托书 1 份 2 页
发明专利请求书 1 份 5 页
实质审查请求书 文件份数：1 份
申请方案卷号：超-231-324-王

提示：

1.申请人收到专利申请受理通知书之后，认为其记载的内容与申请人所提交的相应内容不一致时，可以向国家知识产权局请求更正。

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审 查 员：自动受理
联系电话：010-62356655

审查部门：初审及流程管理部

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Modeling and Control of Differential-Drive Chassis for a Homecare Assistive Robot

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Modeling and Control of Differential-Drive Chassis for a Homecare Assistive Robot

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***Abstract*—With the increasing of the aging population, the demand for homecare services is escalating and the homecare assistive robots are becoming increasingly popular. In this paper, a differential mobile chassis design for a homecare assistive robot is presented. The mobile chassis is made of aluminum sheet and profile, and adopts a two-wheel differential model as the kinematic model. The STM32 single chip microcomputer is used as the cerebellum to control chassis movement, and the NVIDIA Jetson Nano Developer Kit is employed as the brain for perception and decision-making. The software architecture is based on the back-fore ground system and the ROS. A prototype is developed and experiments on simultaneous localization and mapping (SLAM) as well as autonomous navigation experiments are conducted to verify the practicality of the chassis design.**

Keywords—homecare assistive robots, mobile chassis, SLAM, autonomous navigation

I. Introduction

Nowadays, the aging population of the world has become a severe problem. The endowment burden for each household is getting heavier. This leads to a problem that more and more elderly people can only look after themselves at home alone with limited mobility if they have disabilities or underlying diseases [1, 2]. Usually, the elderly is repugnant to be arranged to the nursing home and hiring a nursemaid is not affordable for everyone. Therefore, the homecare assistive robots have arisen wide study as they can be seen as the most potential solution for the care of the home-based elderly.

And the homecare assistive robots can be divided into rehabilitation robots and service robots. The rehabilitation robots are mainly actuated artificial limbs and the robotic suits that enclose the affected limb like an exoskeleton which are designed for recovering the physical function of patients [3-5]. While the work presented in this paper is much more similar to the service robot. There are some excellent examples of fully capable service robot like Care-O-bot [6], Homemate [7] and Hobbit PT2 [8]. They can interact with humans through visual or tactile approaches. And a wheelchair robot is developed for the handicapped especially [9]. The PR2 [10] is another typical homecare assistive robot with dual-arms which can perform chores. Yamazaki *et al.* [11] conduct experiments of using a home-assistant robot to transport things. The most significant thing is that the above contents are all mobile robots with the ability to move autonomously in a domestic environment.

Thus, the research of mobile robots chassis is necessary. According to the steering structure, the chassis can be divided into Ackerman, omnidirectional and differential categories. The design of a wheeled mobile robot using an Ackerman configuration is presented in [12]. And there are many researches on the application of Ackerman structure [13-15]. While a design of omnidirectional chassis for inspection robots is investigated in [16]. Tan *et al.* study the omnidirectional indoor mobile robot system based on multi-sensor fusion [17]. Apparently, omnidirectional chassis is holonomic with arbitrary trajectory. However, its wheels are either poly or mecanum wheels which are very limited for load capacity. As for the differential driven chassis, the common structures are based on

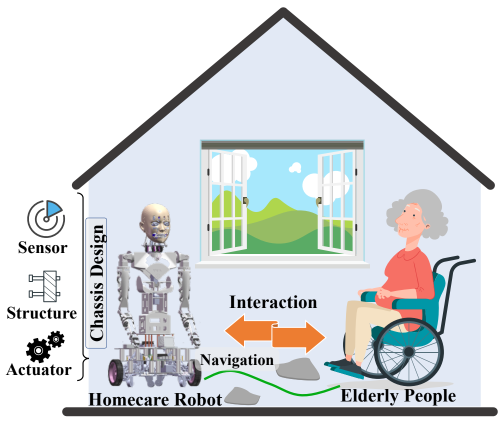


Fig. 1. Homecare assistive robot with a two-wheel differential-drive chassis.

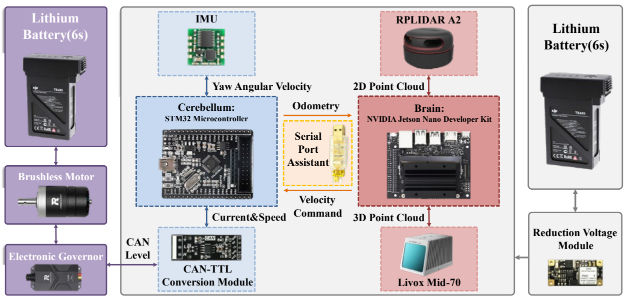


Fig. 2. The electronic configuration of the chassis. The motor and electronic governor with purple background use one lithium battery, and other electronic components and sensors with gray background use another lithium battery.

wheels and crawler. The crawler robots are usually designed for field special tasks operated in irregular terrain [18]. While the wheeled robots are common in various application scenarios [19-20].

In this paper, a two-wheel differential chassis is designed and implemented for home-based assistive robots using aluminum sheet and profile, as shown in **Fig. 1**. Two kinds of suspension structure are designed for the driving and driven wheels respectively to enhance the mobility of the chassis. Furthermore, in consideration of the trade-off between the performance and cost, the commercial electronic components are selected. Specifically, the STM32 single chip microcomputer (SCM) is used as the cerebellum to control chassis movement and the NVIDIA Jetson Nano Developer Kit (Jetson Nano) is applied as the brain for perception and decision-making. The software system in SCM is the back-fore ground system based on multiple interrupts. And the ROS embedded in Jetson Nano plays a role of the high-order algorithm scheduling system. Finally, the SLAM and navigation experiments are conducted using the chassis prototype to verify the design of the chassis.

II. Chassis System Design

A. Kinematic Model

In this work, a two-wheel differential model is employed as the chassis kinematic model, since it can make the chassis rotation center coincide with the geometric center. Due to the constraints of the driving wheels, the chassis can only move along the radial direction of the driving wheels. Thus, the two-wheel differential chassis is non-holonomic which is subject to non-omnidirectional constraints. Though the chassis has 3 DOF, it can only control the linear velocity v_x in the X direction of its own coordinate system and the yaw rate ω.

B. Mechanical Structure

As the chassis is designed for a homecare assistive robot, it must have a certain load capacity to undertake the specific upper body of the robot. Hence, the aluminum sheet and profile are applied to construct the chassis structure. When the robot is moving in a specific place, it will inevitably encounter the problem of wheel slipping which will increase the error of the wheel odometry. And the robot must meet the necessity of steadily passing through the bumpy road when carrying the stuff like pills for the elderly. Therefore, a simplified suspension system is designed for the chassis which only contains the shock absorber. The suspension structures of driving and driven wheels are parallelogram, their difference only lies in the number of shock absorbers and the elastic coefficient of the spring.

C. Electronic Configuration

Considering the stability of the power supply, the dual lithium batteries are used to power the chassis, one for the brushless motor and one for the other electronic components. Thus, the electrical isolation at the hardware level is achieved.

Specifically, the DC brushless motor (RoboMaster M3508 P19) is selected for driving the chassis. The single chip microcomputer with STM32F407ZGT6 is employed as the cerebellum to control the movement of the chassis. And the commercial IMU (Wit-motion JY61P) is adopted to collect inertial readings for the SCM especially the yaw rate. In addition, the Jetson Nano is used as the brain of the chassis. And there are two types of lidar connected with the Jetson Nano, one is RPLIDAR A2 which provides 2D point cloud and the other one is DJI Livox Mid-70 which provides 3D point cloud. The electronic configuration of the chassis is shown in **Fig. 2**.

D. Software Architecture

Tasks in the SCM are sensitive to the execution frequency and priority respectively. Hence, the Interrupt Service Routines (ISR) is adopted to perform different tasks and other processing. The software system in the SCM can be called back-fore ground system. Nevertheless, the interrupt frequency of those tasks like receiving data from hardware port depends on the transmitting terminal which is indeterminate at the coding phase. For those tasks with defined execution frequency, they are performed in the ISR of the internal timer of the SCM.

The Ubuntu 18.04 is installed on the Jetson Nano as the operating system. Next, the ROS Melodic is embedded in the Ubuntu. Thanks to the ROS community, there are plenty of off-the-shelf algorithm packages available for developers. The

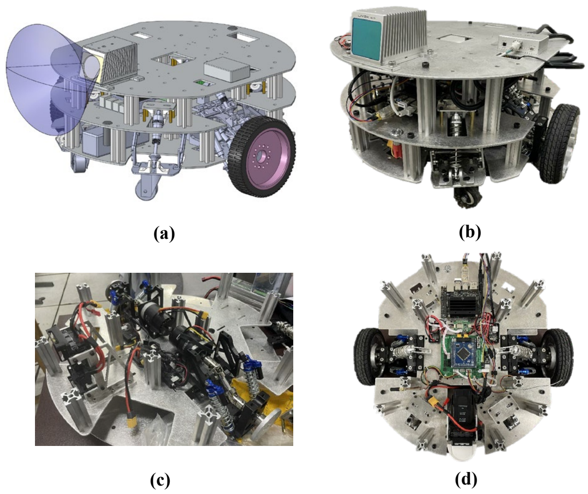


Fig. 3. Integration of the chassis prototype: (a) The 3D model of the chassis prototype; (b) The mock-up of the chassis prototype; (c) Construction of the motor module; (d) Construction of the inside modules.

mature and open-source *Gmapping, LOAM*, *A** and *DWA* algorithms are selected to realize 2D, 3D SLAM and autonomous navigation respectively. To make these algorithms work, there are several custom auxiliary packages need to be created. For instance, the *robot_serial* package contains two nodes is made for communicating with the SCM.

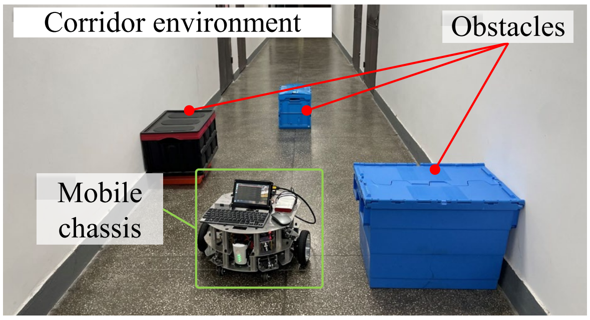
E. *Construction of the chassis prototype*

Based on the design in section II (A-D), a prototype of the chassis for evaluation and experiments on SLAM and navigation is constructed. The prototype weighs 10kg with two driving wheels and four omnidirectional driven wheels. The 3D model and mock-up of the chassis prototype are shown in **Fig. 3**.

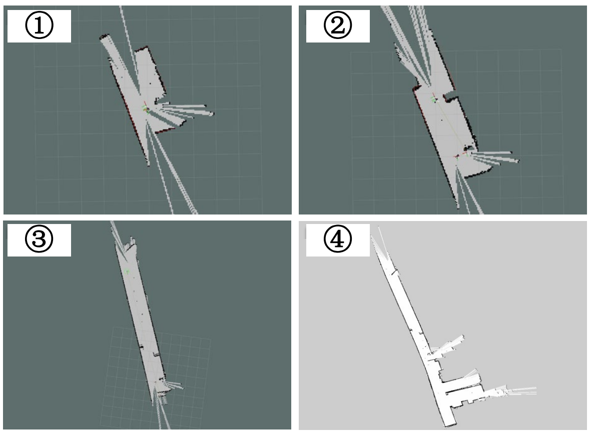
III. Experiments of SLAM and Navigation

A. *2D SLAM Experiments*

The place where to conduct the 2D SLAM experiments is an indoor corridor with three boxes manually set as the obstacles, and it is shown in **Fig. 4(a)**. In the test, the linear and angular velocity of the chassis is limited within 0.5 m/s and 30 °/s respectively in case of the dramatic drift of the wheel odometry. We use the remote control to make the chassis move at a uniform speed and the grid map updates gradually. Eventually, the appearance of the constructed map and the real environment are basically the same. The visualized process and qualitative result of 2D SLAM are shown in **Fig. 4(b)**.

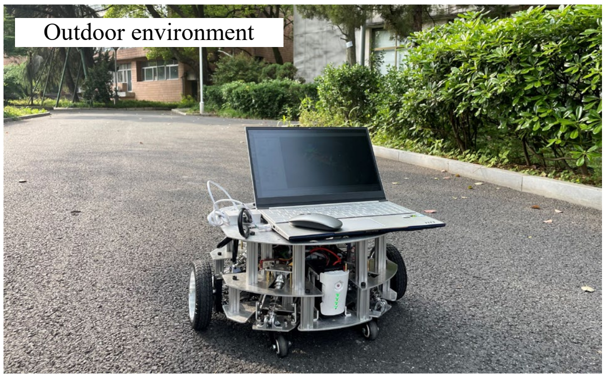


(a)

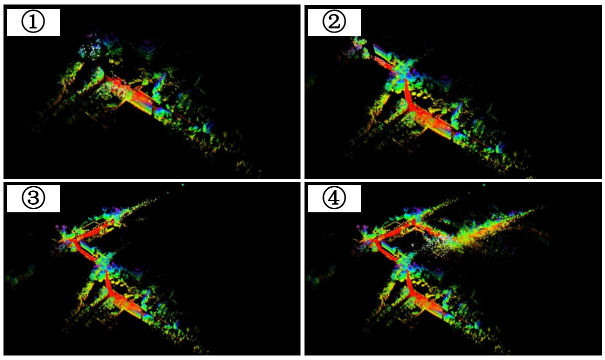


(b)

Fig. 4. The 2D SLAM experiment setup and results. (a) The indoor experiment environment and the obstacles. (b) The qualitative results of 2D SLAM



(a)



(b)

Fig. 5. The 3D SLAM experiment setup and results. (a) The outdoor experiment environment with the trees and buildings. (b) The qualitative results of 3D SLAM.

B. *3D SLAM Experiments*

Furthermore, the outdoor 3D SLAM experiments using *LOAM* algorithm on a large scale are carried out. The experiment environment and qualitative results of 3D SLAM are shown in **Fig. 5(a)** and **Fig. 5(b)** respectively.

C. *Autonomous Navigation*

The *A** and *DWA* algorithms are applied as the global and local path planning approach respectively. And the *DWA* is capable of avoiding dynamic obstacles naturally. Additionally, the visualization tool Rviz which is a component of ROS is used to set the destination for the chassis in an interactive way without coding. The experiments environment is the same with 2D SLAM and the navigation process is shown in **Fig. 6**. During the test, the chassis runs fully autonomous except setting the goals manually. The tolerance of the yaw angle and position after reaching the destination are set to 5° and 0.1 meters respectively. As it can be seen, when the target is given, the chassis can plan a dynamic path which will be adjusted when approaching the obstacles. And the chassis performs well on tracking the planned trajectory and reaches the destination accurately.

IV. Conclusion

In this research, a chassis design for a homecare assistive robot has been presented. The chassis adopts two-wheel differential model and has two driving wheels and four omnidirectional driven wheels. The aluminum sheet and profile are selected to construct the chassis. And the electronic

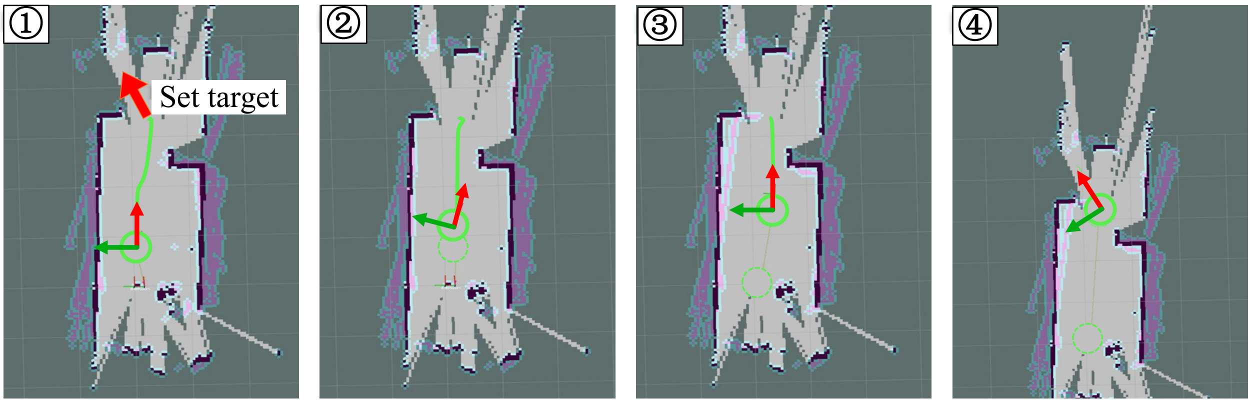


Fig. 6. The autonomous navigation experiment. The tail and direction of the red arrow are the destination for the next move and the orientation of the chassis after reaching the destination respectively. The green lines are the real-time planned trajectories. The green circle represents the chassis.

configuration has been specified where the SCM and the Jetson Nano are used for the control of chassis movement and perception and decision-making. Moreover, a prototype of the chassis has been built. The qualitative results of 2D and 3D SLAM experiments demonstrate that the appearance of the map constructed by the chassis is basically identical with the real scene whether in 2D or 3D scenario. And the qualitative result of navigation illustrates that the chassis can plan and track the path and avoid obstacles autonomously. For future work, quantitative experiments of various SLAM and navigation algorithms will be conducted.

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REFERENCES

[1] H. Lv, G. Yang, H. Zhou, X. Huang, H. Yang, and Z. Pang, "Teleoperation of Collaborative Robot for Remote Dementia Care in Home Environments," *IEEE Journal of Translational Engineering in Health and Medicine,* vol. 8, pp. 1-10, 2020.

[2] H. Lv *et al.*, "GuLiM: A Hybrid Motion Mapping Technique for Teleoperation of Medical Assistive Robot in Combating the COVID-19 Pandemic," *IEEE Transactions on Medical Robotics and Bionics,* vol. 4, no. 1, pp. 106-117, 2022.

[3] A. Roy *et al.*, "Robot-aided neurorehabilitation: a novel robot for ankle rehabilitation," *IEEE Transactions on Robotics,* vol. 25, no. 3, pp. 569-582, 2009.

[4] Z. Qian and Z. Bi, "Recent development of rehabilitation robots," *Advances in Mechanical Engineering,* vol. 7, no. 2, p. 563062, 2015.

[5] J. A. Blaya and H. Herr, "Adaptive control of a variable-impedance ankle-foot orthosis to assist drop-foot gait," *IEEE Transactions on Neural Systems and Rehabilitation Engineering,* vol. 12, no. 1, pp. 24-31, 2004.

[6] R. Kittmann, T. Fröhlich, J. Schäfer, U. Reiser, F. Weißhardt, and A. Haug, "Let me introduce myself: I am Care-O-bot 4, a gentleman robot," *Mensch und Computer 2015–proceedings,* 2015.

[7] X. Zhao, A. M. Naguib, and S. Lee, "Octree segmentation based calling gesture recognition for elderly care robot," in *Proceedings of the 8th International Conference on Ubiquitous Information Management and Communication*, 2014.

[8] M. Bajones *et al.*, "Hobbit: providing fall detection and prevention for the elderly in the real world," *Journal of Robotics,* vol. 2018, 2018.

[9] S. Kumar, P. Rajasekar, T. Mandharasalam, and S. Vignesh, "Handicapped assisting robot," in *2013 International Conference on Current Trends in Engineering and Technology*, 2013.

[10] J. Bohren *et al.*, "Towards autonomous robotic butlers: Lessons learned with the PR2," in *2011 IEEE International Conference on Robotics and Automation*, 2011.

[11] K. Yamazaki *et al.*, "Home-assistant robot for an aging society," *Proceedings of the IEEE,* vol. 100, no. 8, pp. 2429-2441, 2012.

[12] R. A. Orozco-Velazquez *et al.*, "Ackerman mobile robot with arm," in *2016 International Conference on Mechatronics, Electronics and Automotive Engineering*, 2016.

[13] Y. Zhang, J. Huang, and J. Zhang, "Research on multi-directional automatic parking of Ackerman car model such as vertical parking, parallel parking and oblique parking," in *2022 2nd International Conference on Computer Science, Electronic Information Engineering and Intelligent Control Technology*, 2022.

[14] A. J. Weinstein and K. L. Moore, "Pose estimation of Ackerman steering vehicles for outdoors autonomous navigation," in *2010 IEEE International Conference on Industrial Technology*, 2010.

[15] A. Gupta, R. Divekar, and M. Agrawal, "Autonomous parallel parking system for Ackerman steering four wheelers," in *2010 IEEE International Conference on Computational Intelligence and Computing Research*, 2010.

[16] Z. Q. Li, W. G. Li, L. L. Wang, and S. X. Ge, "Research on omnidirectional movement and environment detection function of inspection robot," in *2020 5th International Conference on Mechanical, Control and Computer Engineering*, 2020.

[17] X. Tan, S. Zhang, and Q. Wu, "Research on Omnidirectional Indoor Mobile Robot System Based on Multi-sensor Fusion," in *2021 5th International Conference on Vision, Image and Signal Processing*, 2021.

[18] T. Hagiwara, Y. Yamamura, Y. Namima, J. Ogami, and L. Pengfei, "Production of Crawler Robot with Sub Crawler and Verification of Traversing Ability," in *2021 Second International Symposium on Instrumentation, Control, Artificial Intelligence, and Robotics*, 2021.

[19] J. Meng, A. Liu, Y. Yang, Z. Wu, and Q. Xu, "Two-wheeled robot platform based on PID control," in *2018 5th International Conference on Information Science and Control Engineering*, 2018.

[20] Z. Fan, Q. Qiu, and Z. Meng, "Implementation of a four-wheel drive agricultural mobile robot for crop/soil information collection on the open field," in *2017 32nd Youth Academic Annual Conference of Chinese Association of Automation*, 2017.